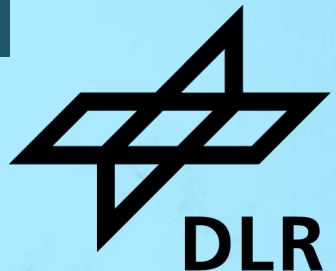


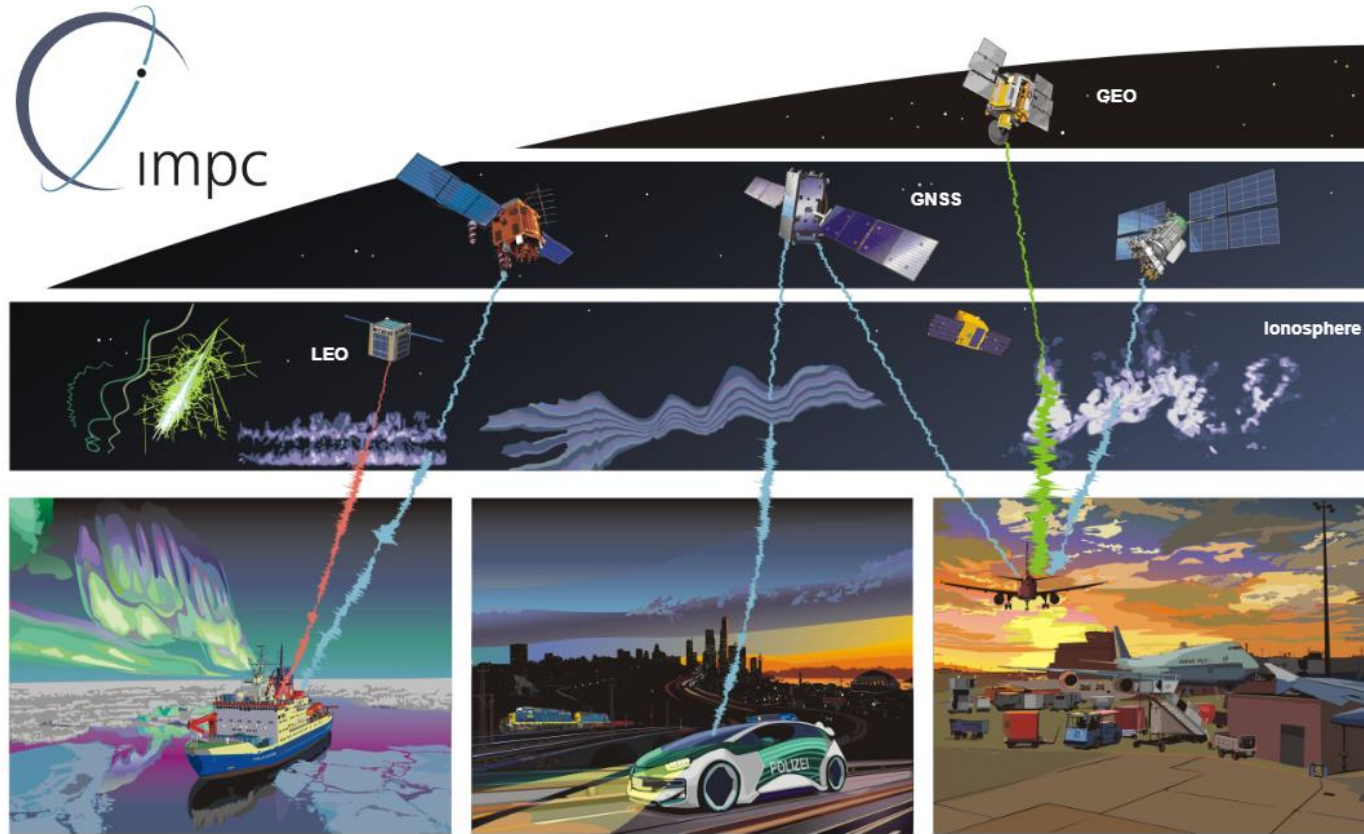
THE IONOSPHERIC DISTURBANCE INDEX (DIX-SG) AND ITS PERFORMANCE UNDER CONTINUOUS OPERATION

Jens Berdermann, Volker Wilken, Martin Kriegel, Paul David and
Youssef Tagargouste

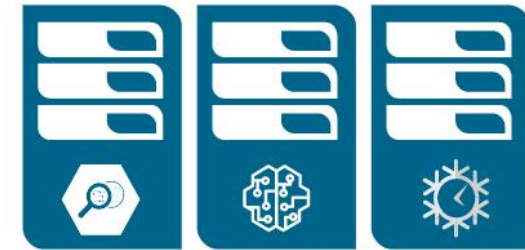
COSPAR, PSW.3-0003-24, Busan, 2024



Motivation



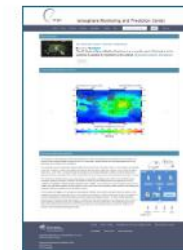
Global ground and space based observations



Monitoring Modelling Prediction



Data Archive since 1995



Web Portal



Tailored Services



User Help Desk



Commercial Applications Government Science Public Interest

- There is the need to support customers providing services based on transient radio links with an adequate ionospheric index and an appropriate scale

42nd COSPAR Scientific Assembly

14.-22.07.2018, Pasadena Convention Center



PSW.3:

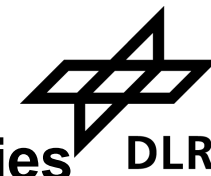
From Ionospheric Indices towards
Standardised Activity Scales for
Space Weather Services

Main Scientific Organizer: Jakowski, Norbert

Deputy Organizer: Terkildsen, Michael

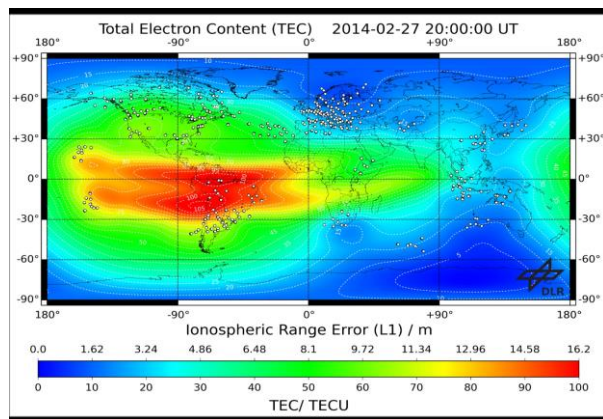
- DIXSG has been introduced (PSW.3-0008-18 ESTIMATING THE DEGREE OF IONOSPHERIC PERTURBATIONS USING AN IONOSPHERIC INDEX)
- The workshop has selected DIXSG as a potential candidate for the development of an ionospheric weather scale
- Further validation as well as real-time assessment needed
- ISWAT Team (ID: G2B-04, Ionospheric perturbation indices and scales) supports the development of an internationally recognized ionospheric weather scale

Why is the definition of an comprehensive ionospheric index and a related scale so challenging?

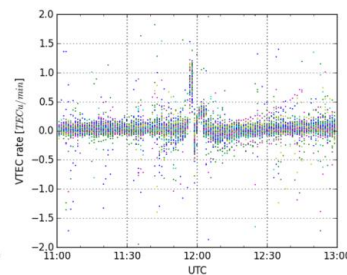
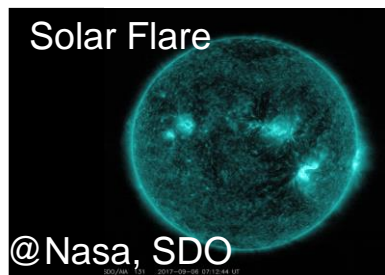
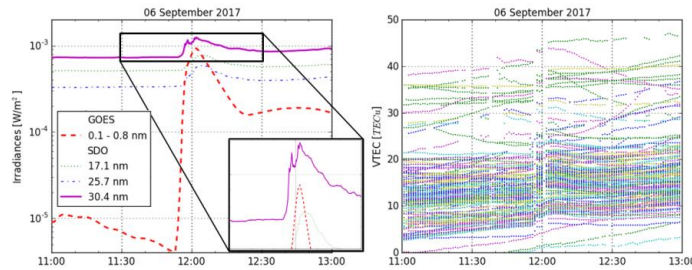


Regional dependencies

Ionospheric Storm

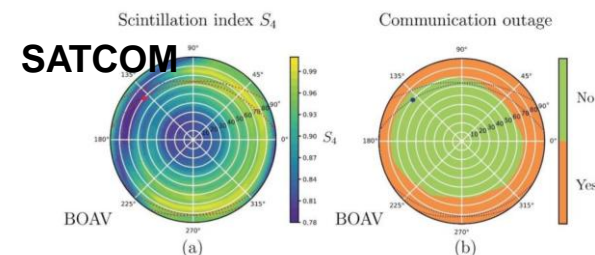
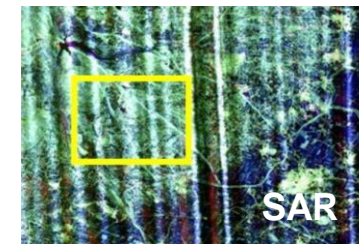


Temporal dependencies

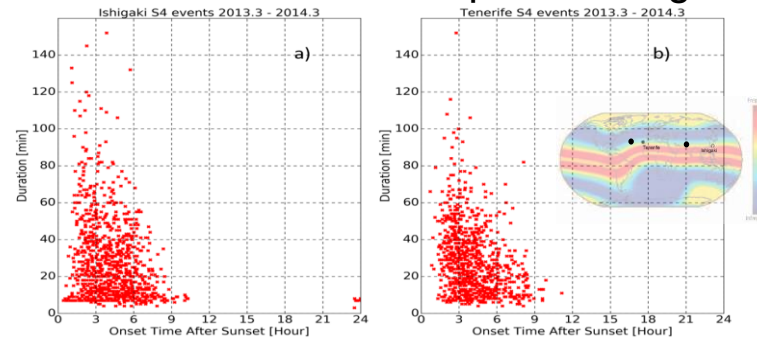


Technical dependencies

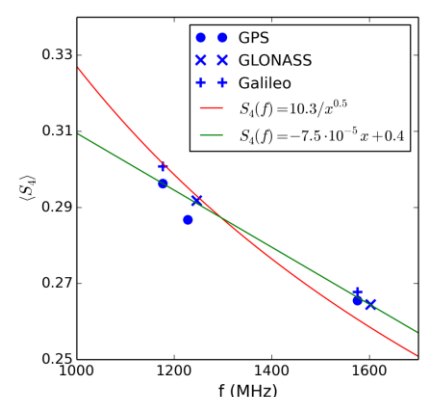
System dependence



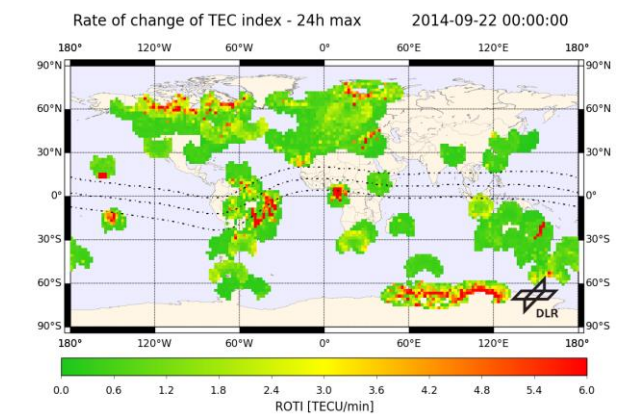
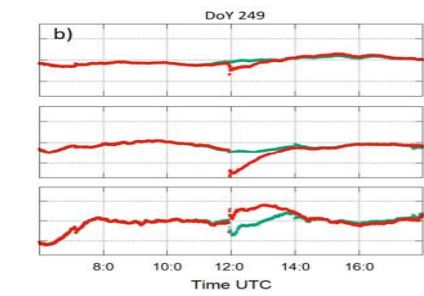
Scintillation occurrence in equatorial region



Frequency dependence



GNSS PPP (single versus dual)



Plenty of different use cases!



Disturbance Ionosphere Index Spatial Gradient (DIXSG)

Simple but effective



ROT - Rate of TEC

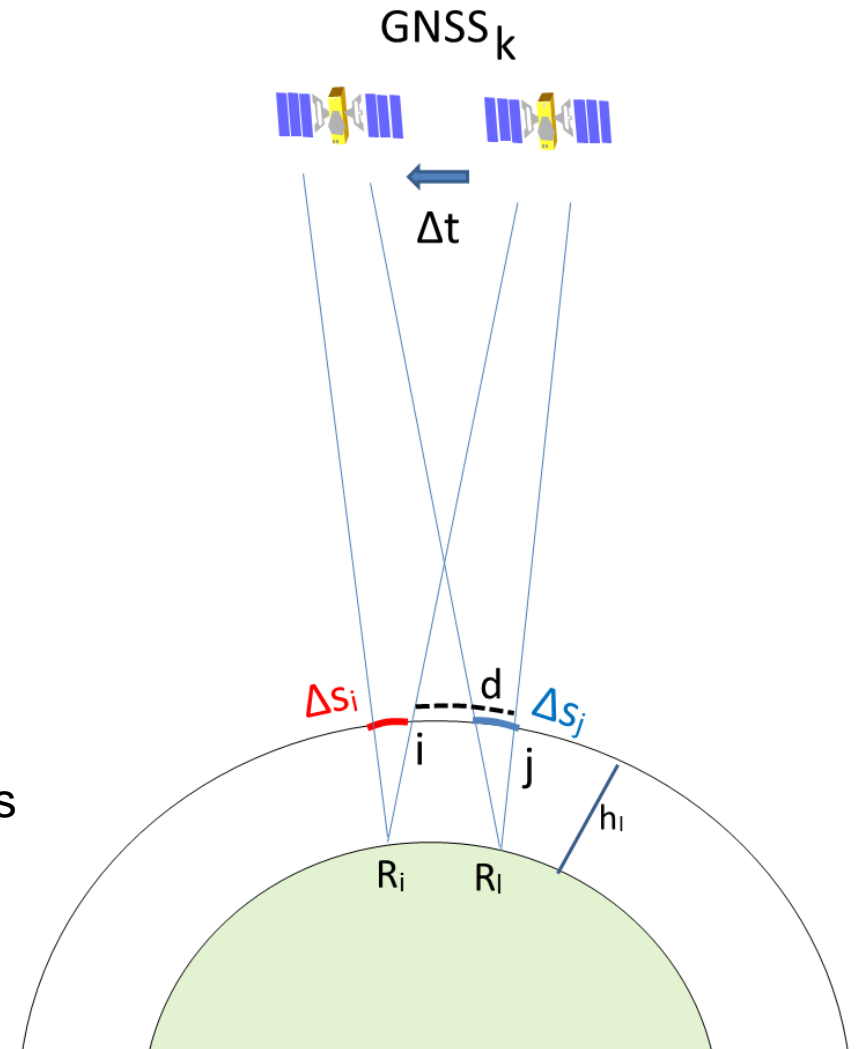
$$cROT_i^k = \left| \frac{\Delta STEC_i^k}{\Delta t \cdot \Delta s_i} \right|$$

$$DIXSG(cROT_{(level)})_{i,j}^k = \left(\frac{|cROT_i^k - cROT_j^k|}{cROT_{(level)}} \right)^3 \left(\frac{d}{D} \right)^{-1}$$

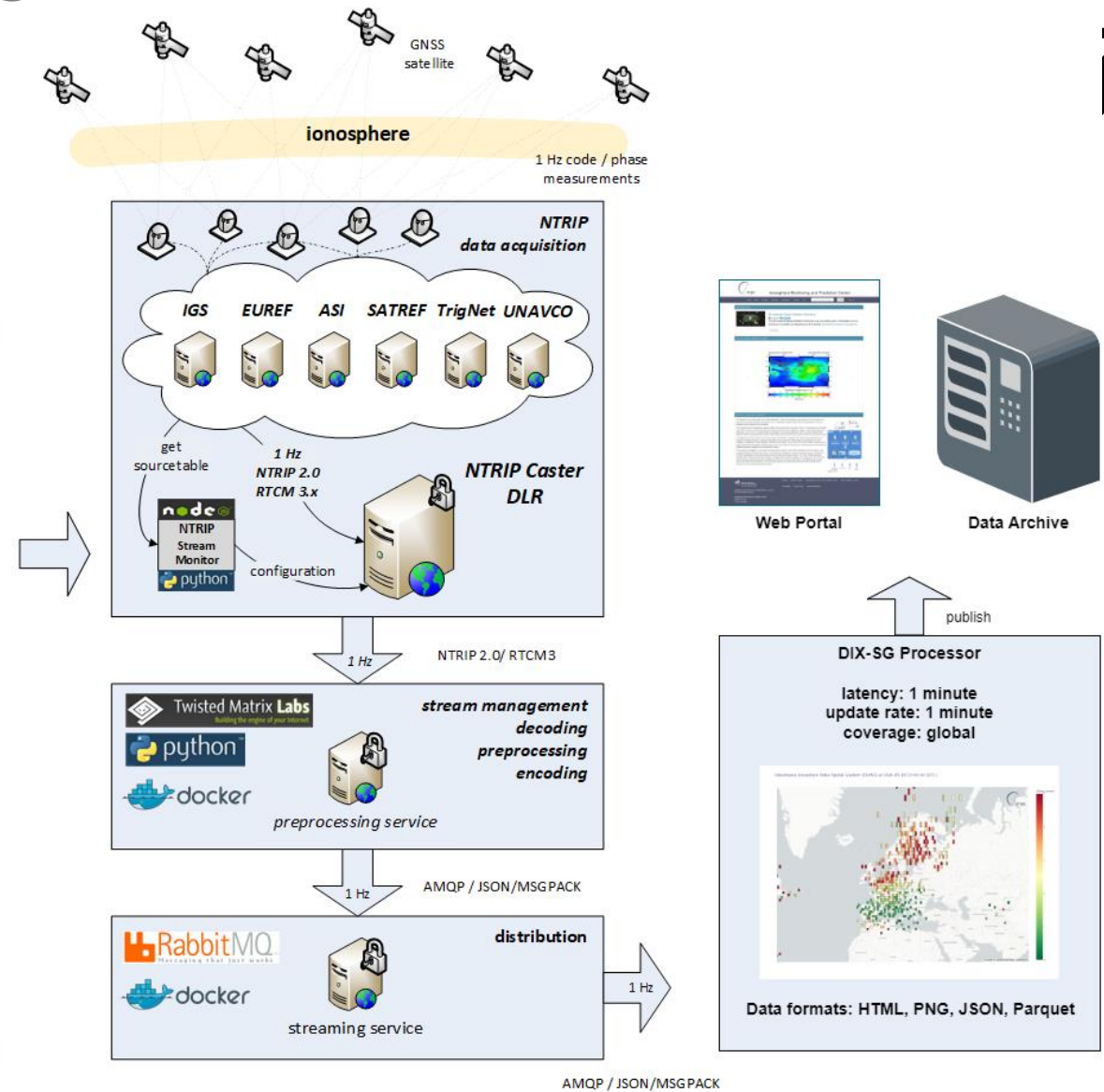
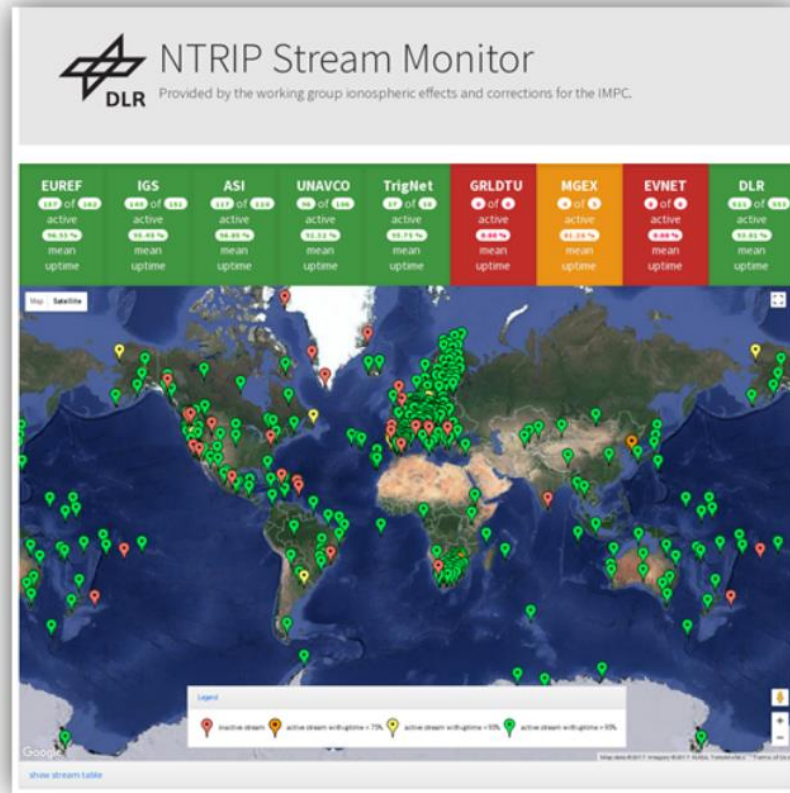
$$DIXSG_{(5-Level)} = \sum_{L=1}^5 DIXSG(cROT_{(level)}(L))$$

$$DIXSG_p = \frac{1}{N} \cdot \sum DIXSG_{(5-Level, \max(1^\circ \times 1^\circ))}$$

- The DIXSG is scalable in its sensitivity to the strength of perturbations
- Possible to choose different levels depending on the application.

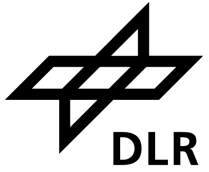


Real time processing of DIX-SG



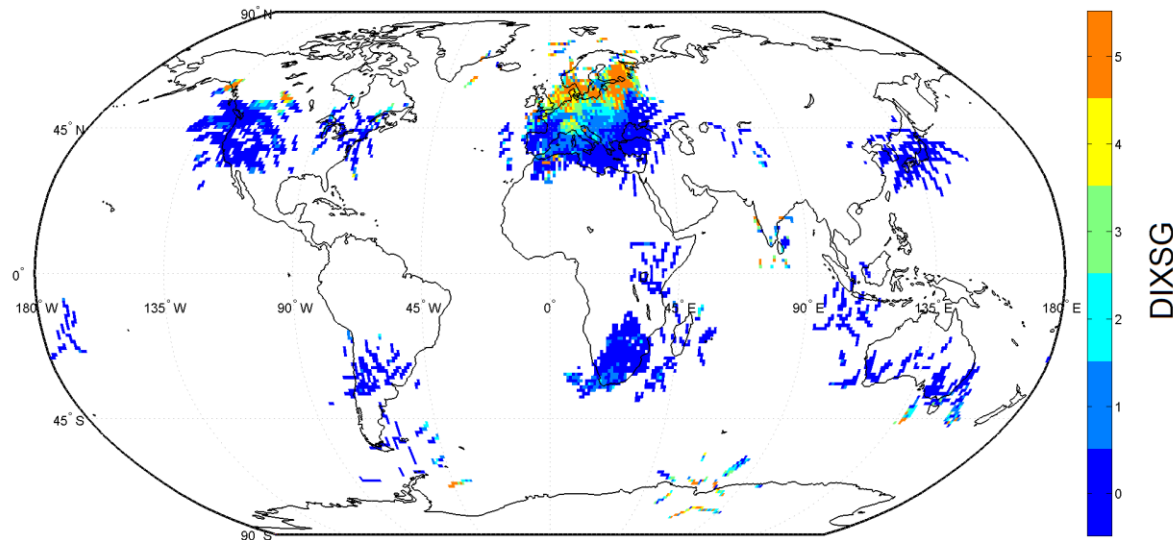
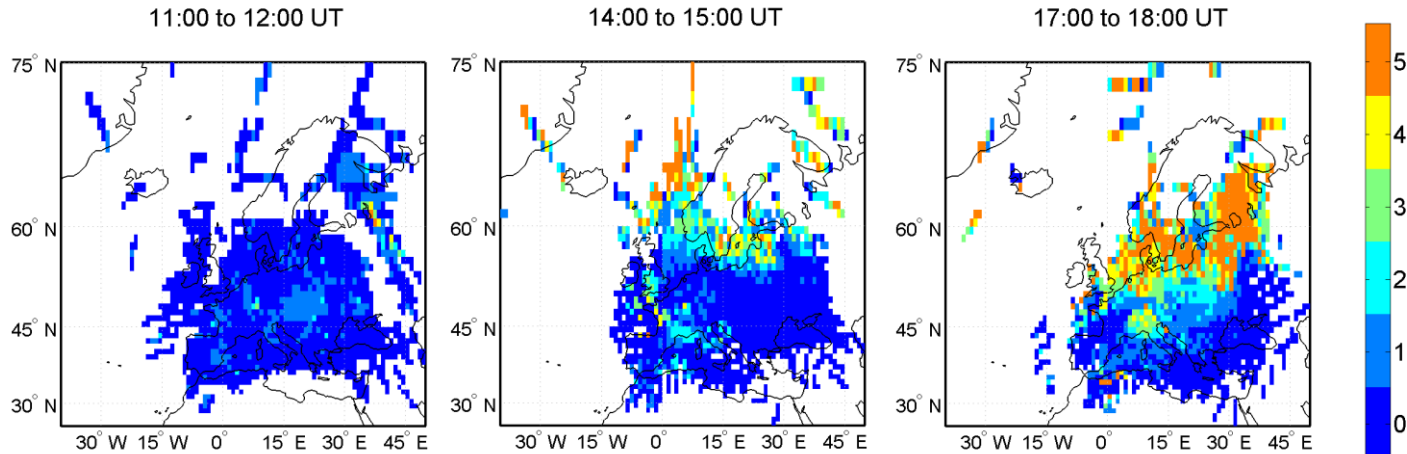
The scale can be optimized to the size of the considered ionospheric disturbances (the minimum distance is of course dependent on the density of the used receiver grid)

DIXSG test and threshold adjustment for the 5 level scale



St. Patrick's Day Storm

17-Mar-2015 (DOY: 076)



Storm events used for to determine the threshold among others are:

- Oct. 29 – Nov. 1 2003 (Halloween Storm)
- Nov. 19 – 22 , 2003
- March 16 – 20, 2015 (St. Patrick-Storm)
- June 22 – 26, 2015
- Dec. 19 – 24, 2015

Five level were finally chosen to fix the sensitivity of the index (50, 100, 150, 200 and 250) and d_{\min} was set to 10km and d_{\max} resp. D to 1000km.

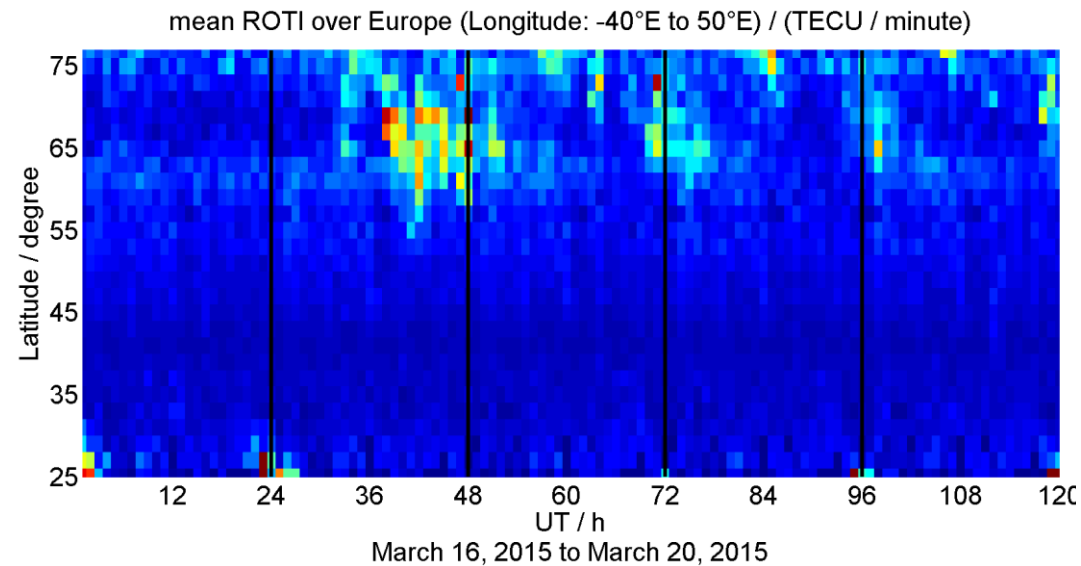
Application of the DIXSG to ionospheric storms

Comparison with ROTI

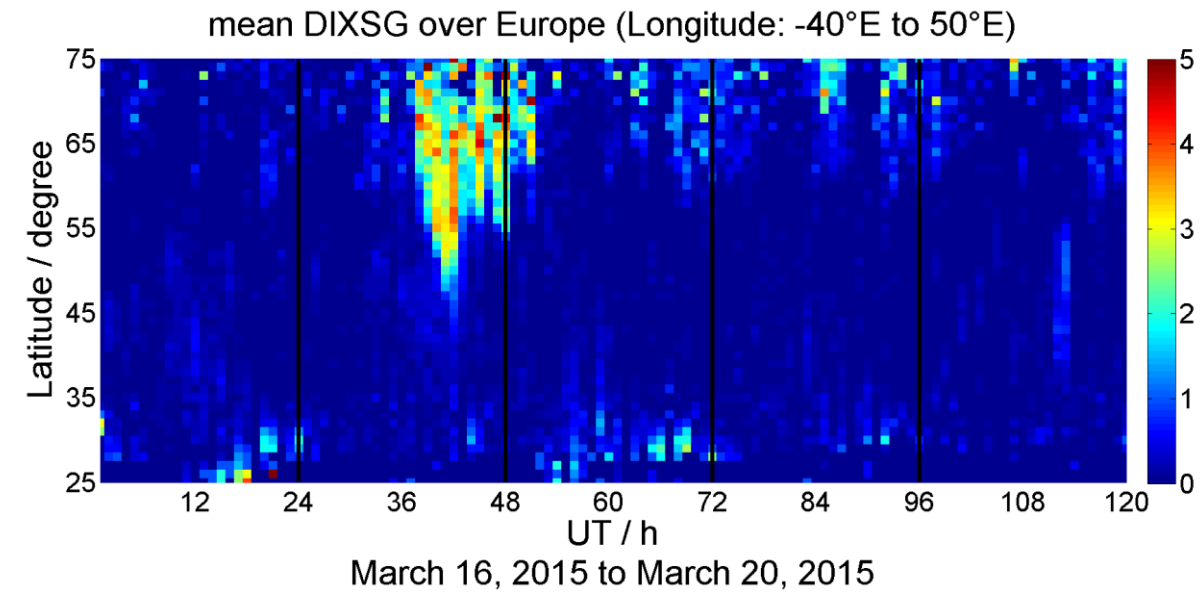


St. Patrick's Day Storm

ROTI



DIX



ROTI versus DIXSG

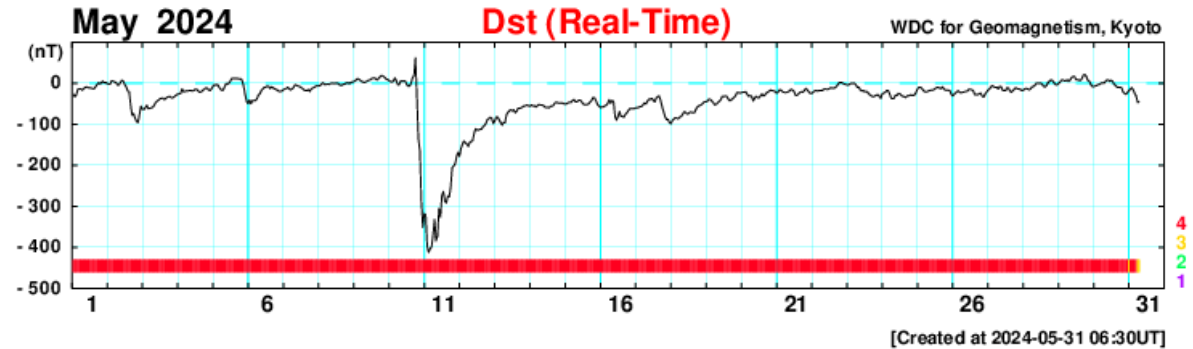


- Both indices are easy to calculate and free of model assumptions, calibration methods or geometry corrections
- Both indices can cover larger areas
- ROTI is very well established and widely used
- DIXSG is more flexible and customizable to specific user needs
 - The values can be selected by direction (e.g. North-South only)
 - The scales of the considered ionospheric disturbances of interest can be filtered (depending on GNSS ground receiver network geometry)
 - The number and values of thresholds can be adopted to specific application requirements
 - The values can be disseminated in a discrete simplified way as an integer scale

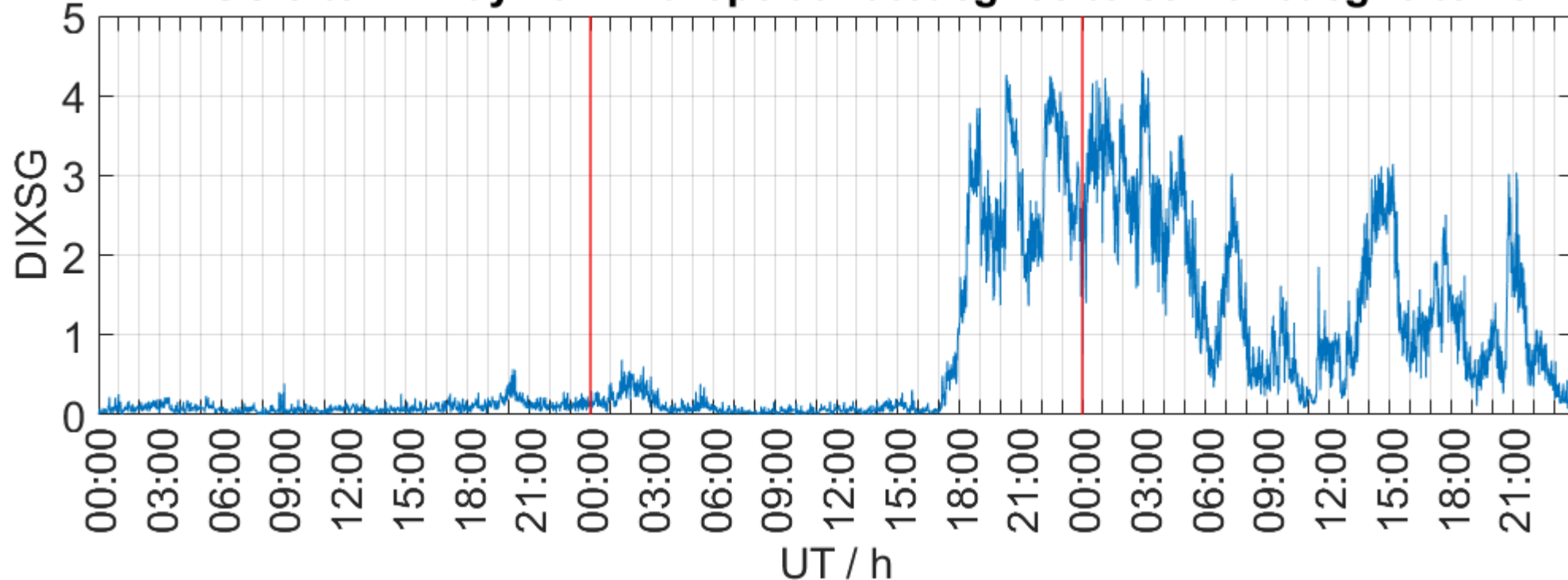
Ionospheric Storm („Motherday Event“) 09-11.05.2024



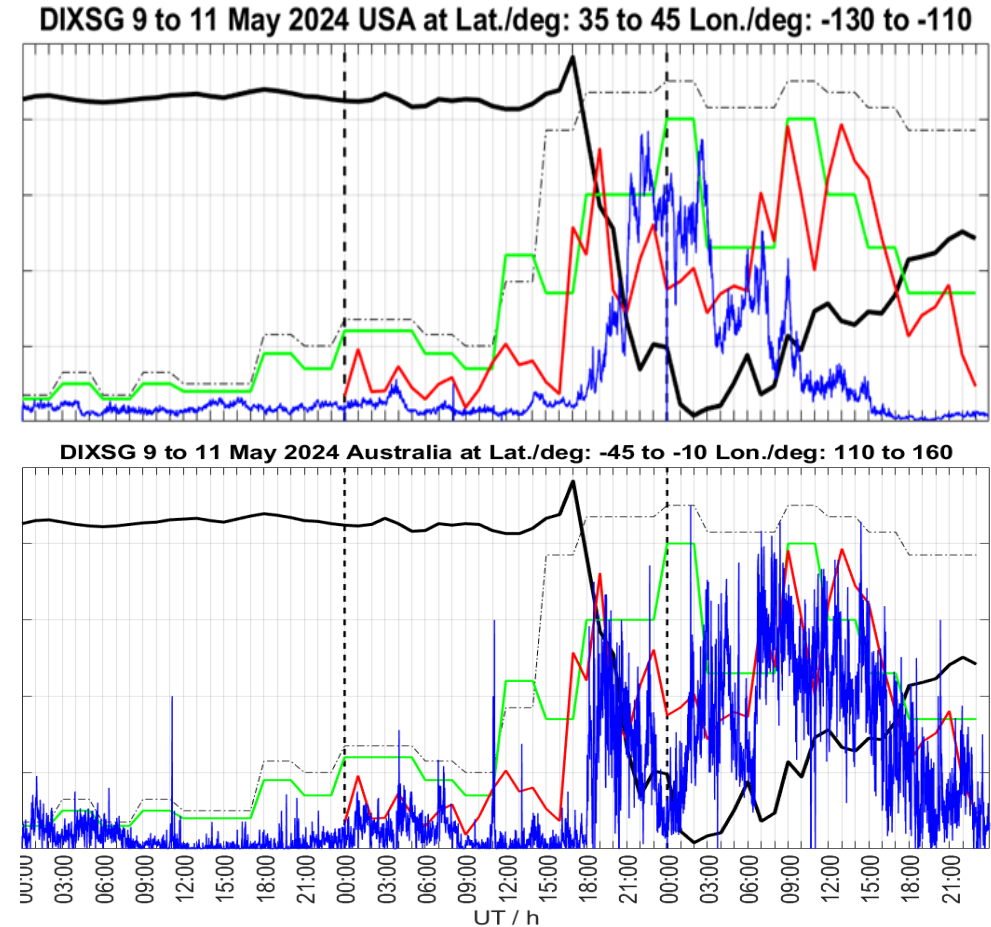
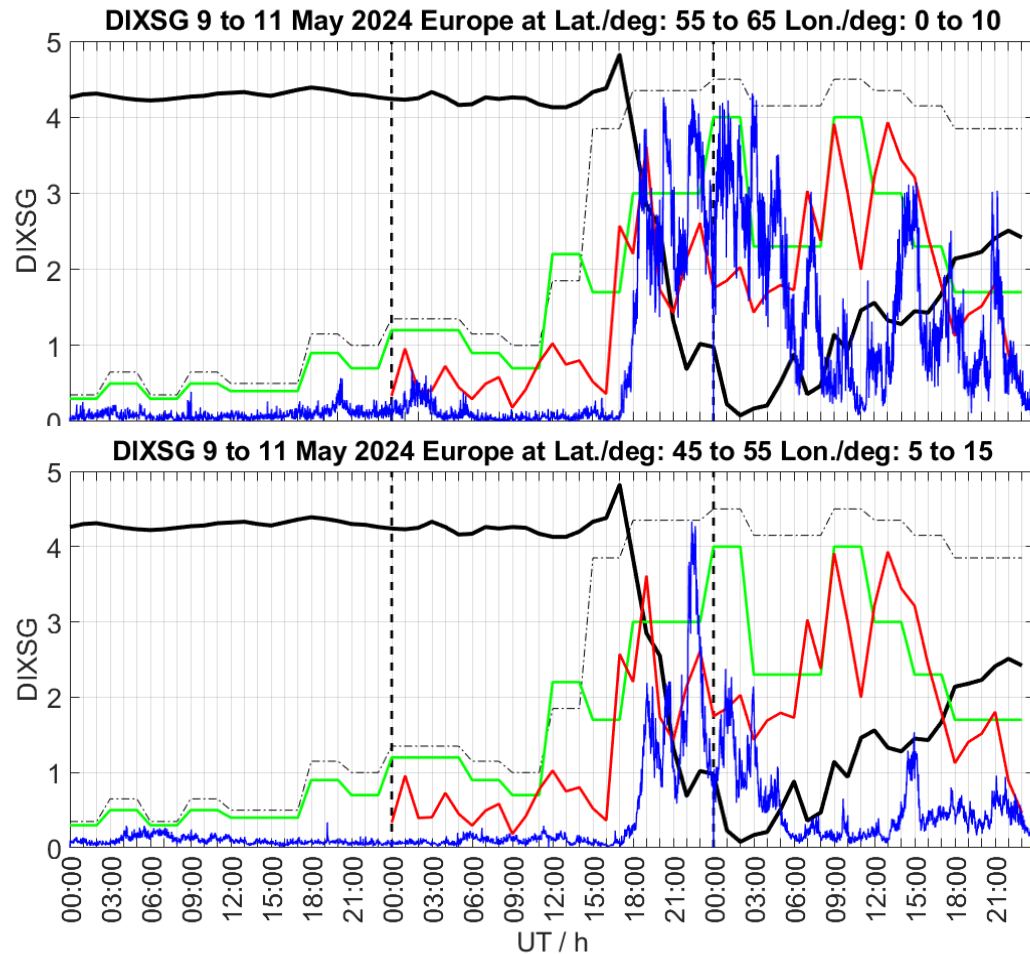
Mean DIXSG Europe
(Lat. 55° to 65°, Lon. 0° to 10°)



DIXSG 9 to 11 May 2024 Europe at Lat./deg: 55 to 65 Lon./deg: 0 to 10



Comparison Mean DIXSG with geomagnetic Indices



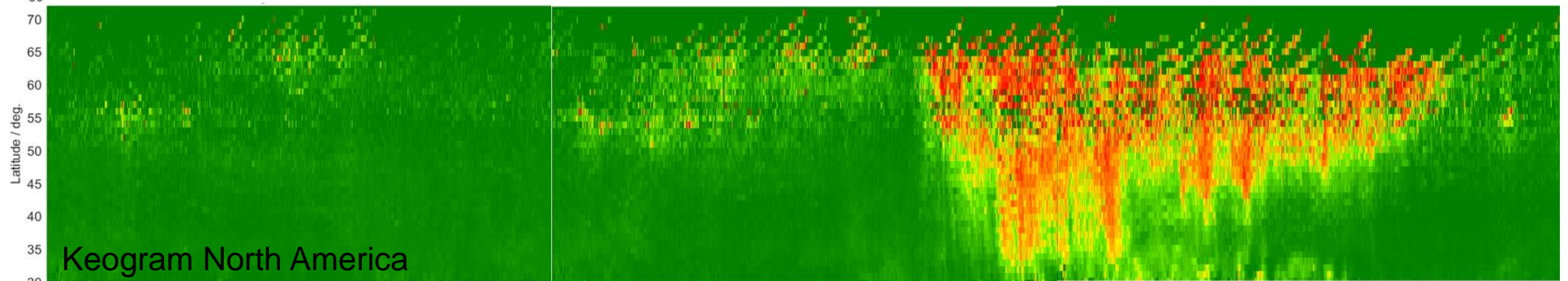
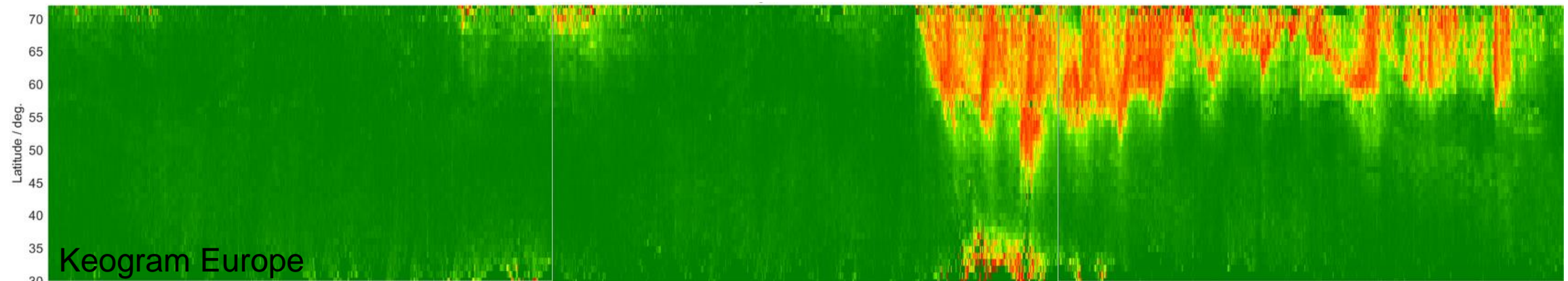
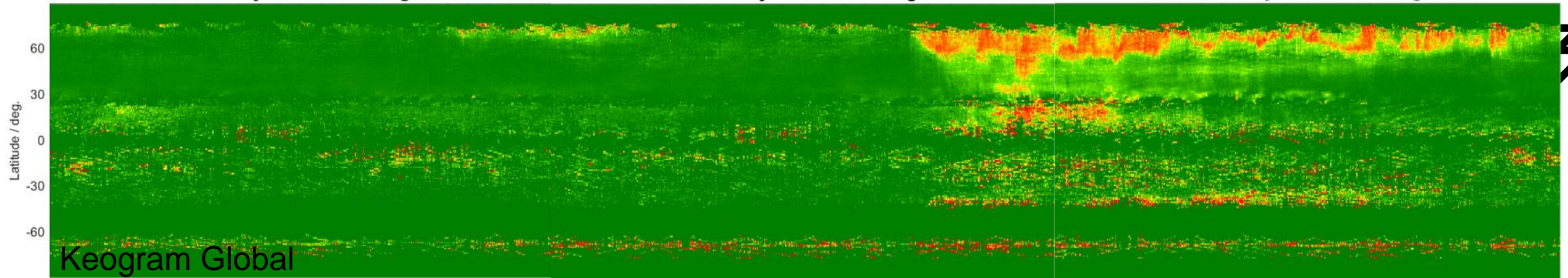
blue line: DIXSG, thick black line: $Dst / nT (* 0.01 + 4.2)$
 red line: $AE / nT (* 0.002)$, green line: $ap / nT (* 0.1)$, dash dotted thin black line: $kp (* 0.5)$

blue line: DIXSG, thick black line: $Dst / nT (* 0.01 + 4.2)$
 red line: $AE / nT (* 0.002)$, green line: $ap / nT (* 0.1)$, dash dotted thin black line: $kp (* 0.5)$

DIXSG 9 May 2024 DOY 130 global

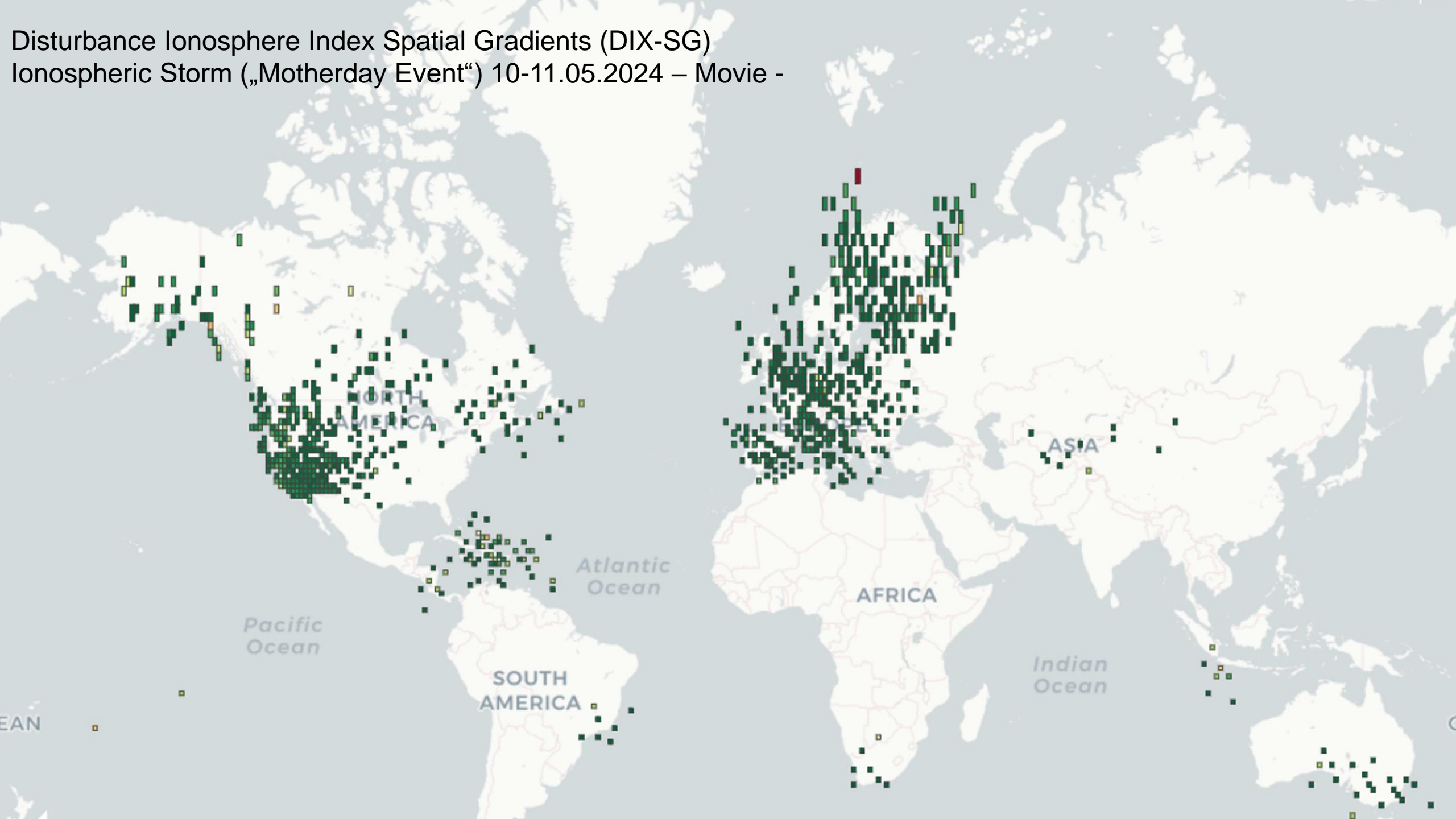
DIXSG 10 May 2024 DOY 131 global

DIXSG 11 May 2024 DOY 132 global



UT / h

Disturbance Ionosphere Index Spatial Gradients (DIX-SG)
Ionospheric Storm („Motherday Event“) 10-11.05.2024 – Movie -



Access to the DIXSG Product



Ionosphere Monitoring and Prediction Center

About News Products Warnings Applications Projects FAQ Search the IMPC website... Login Sign up

- Total Electron Content
 - Near Real-Time TEC
 - NRT TEC, Europe
 - NRT TEC, Global
 - Forecast TEC
 - 1 h FC TEC, Europe
 - 1 h FC TEC, Global
 - Beacon TEC Data
 - Neustrelitz
- Ionospheric Perturbations
 - Rate of Change of TEC Index
 - 1 min mean ROTI, Europe
 - 1 min mean ROTI, Global
 - 1 min max ROTI, Europe
 - 1 min max ROTI, Global
 - Equivalent Slab Thickness
 - Juliusruh
 - Pruhonice
 - Electron Density
 - Electron Density Layers
 - NmF2 Reconstructed
 - NmF2 Model
 - Swarm Ionospheric Gradients
 - Ne Gradient Ionosphere index (NEGIX)
 - TEC Gradient Ionosphere index (TEGIX)
 - Local Scintillation Measurements
 - Disturbance Ionosphere Index Spatial Gradients (DIX-SG)

Disturbance Ionosphere Index Spatial Gradients (DIX-SG)

Latest Data

The ionosphere is the largest natural source of error for trans-ionospheric signals and existing geomagnetic or solar indices can only provide global and indirect information. Therefore, a temporally and spatially resolved ionospheric disturbance index is needed that objectively describes the current level of disturbance to the system and services for operators.

We have developed a prototype ionospheric disturbance index (DIX-SG) that is able to describe the ionospheric disturbance level with high spatial and temporal resolution. The index is based on measurements from 1Hz real time GNSS networks and provides a clear picture about global and regional ionospheric disturbances and their strength based on a simple but powerful numerical approach. As a real-time indicator that objectively and reliably describes the extent and strength of ionospheric disturbances, the DIX-SG could form an essential basis for future global space weather services.

Disturbance Ionosphere Index Spatial Gradient (DIXSG) at 2024-07-14 03:25:00 [UTC]



The DIX-SG measurements are mapped into a regular grid (1°x1° lat/lon). Each grid cell presents the mean of the DIX-SG measurements located in this cell.

Product Specification

External parties	German Federal Agency for Cartography and Geodesy
Data providers	IGS, EUREF, ASI, Greenland network of the Technical University of Denmark, UNAVCO
Input data	GPS dual-frequency measurements
Input sampling rates	1s
Reliability of data source	Data is preprocessed by DLR including e.g. cycle slip detection
Region of sensors	Global
Single-layer shell height	400 km
Spatial resolution	1° x 1° latitude-longitude-bins
Boundaries of grid	global
Temporal resolution	1 min
Time information	UTC Time
Reference coordinate system	ECEF coordinate system with WGS84 reference ellipsoid
Algorithms	The DIXSG algorithm is published: https://doi.org/10.1051/swsc/2018008 V. Wilken et al. (2018) An ionospheric index suitable for estimating the degree of ionospheric perturbations, J. Space Weather Space Clim. 8 A19
File format	JSON: this file format includes metadata and data

Access: <https://impc.dlr.de/products/ionospheric-perturbations/dix-sg>

- The latest image is shown
- When you log in you will also find a link to download the latest data file
- The website currently holds 7 days and synchronizes every 3 minutes with the database, which is updated every minute

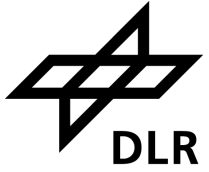
You can click on the image to open an interactive view

Summary

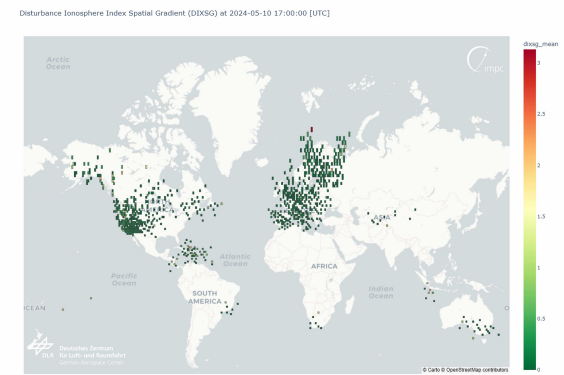
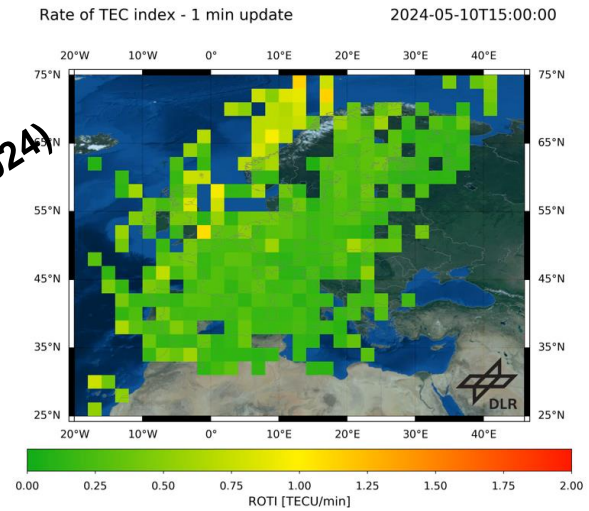
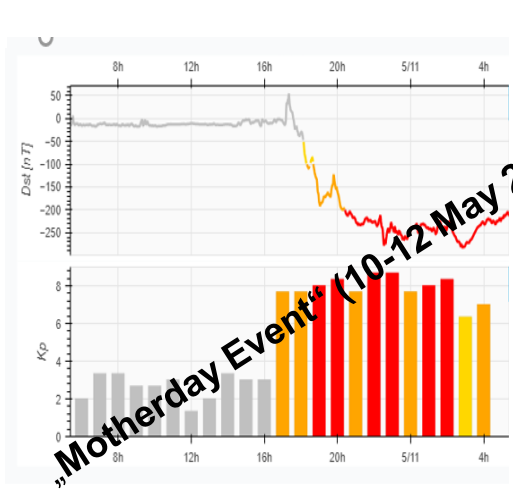
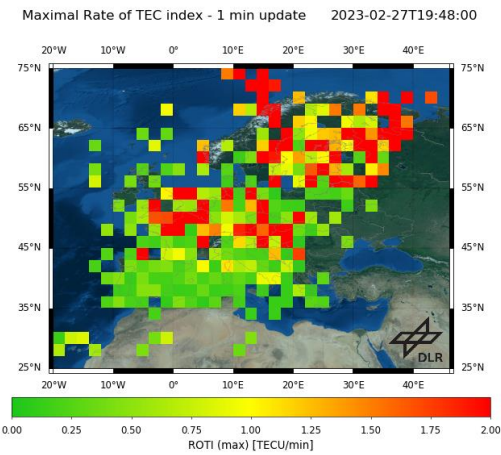
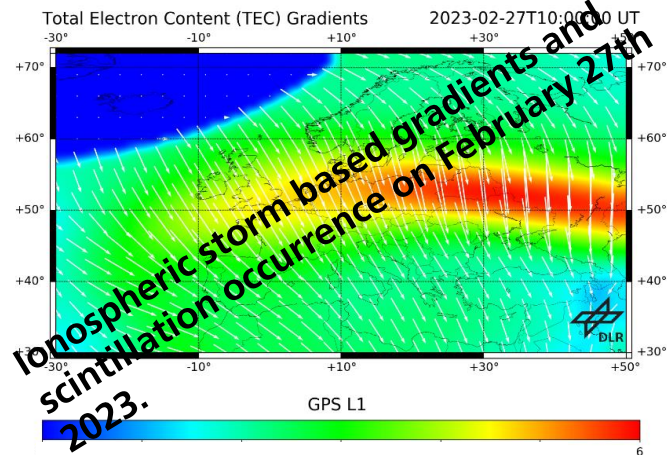
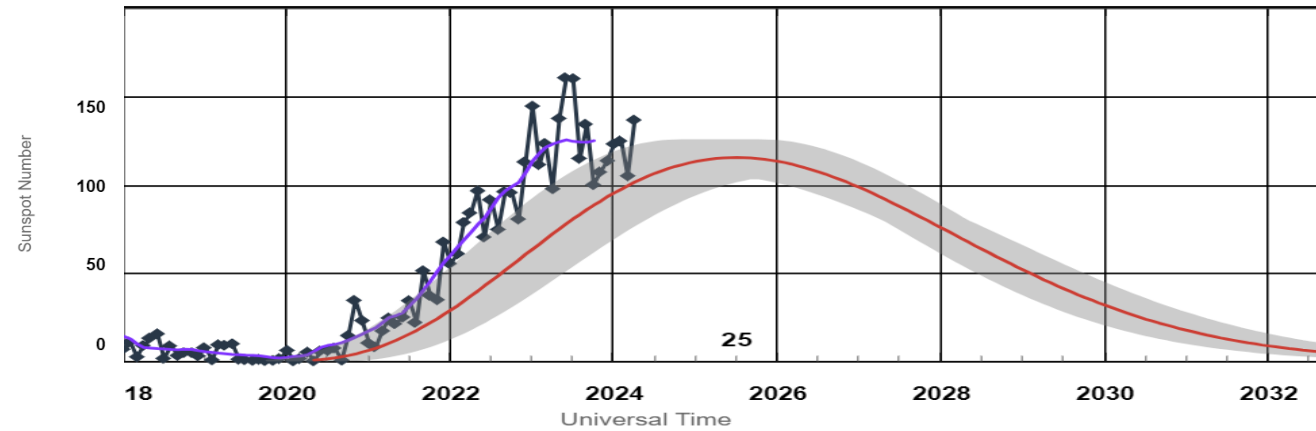


- Disturbance Ionosphere Index-Spatial Gradients (DIXSG) is an Index for estimating ionospheric gradients using rate of TEC measurements
- Time resolution and latency is in the order of the sampling time (< 1min)
- DIXSG has been computed for different storms indicating the degree of ionospheric perturbation degree scaled on 5 activity levels
- A comparison with ROTI indicates that DIXSG is a flexible and useful approach
- DIXSG on global scale is closely related to the Dst
- DIXSG reacted to TEC gradients caused by the Ionospheric Storm (Mother's day Event on 10 May 2024 and the following days immediately and properly (i.e. the course of the storm could be observed and described accurately and simplified by the index in real time)
- Since January 2024, the DIXSG-processor is in continuous operation at the IMPC

Outlook



ISES Solar Cycle Sunspot Number Progression



- We are now in an optimal phase within the 11-year solar cycle to study performance of indices in a real time environment and to evaluate their benefit in respect to the impact of Space Weather on various technologies (maximum solar activity 2024-2026).
- Please try out and use the DIXSG Index for analyses and validation

Advertisement: Related Talks



Panel SW.3: Preparation for a New Ionospheric Space Weather Scale for Transionospheric Radiowave Propagation

Wednesday, 17.07.2024 EC1-314

- **09:30** PSW.3-007-24 *Norbert Jakowski et al*

Ionospheric Indices GIX and SIDX and related perturbation scales

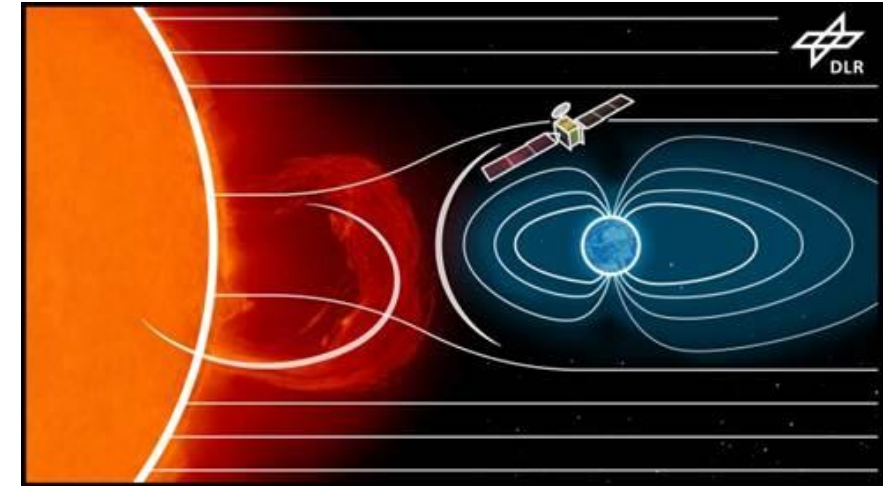
- **09:45** PSW.3-008-24 *Juan Andrés Cahuasqui et al*

Characterisation of the topside Ionosphere using Swarm data the TEGIX and NeGIX indices

Thank you!



Artist: Dmytro Vasylyev



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